The impact of blue light on non-visual brain functions changes with age

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Introduction:
Aging is associated with decreased sleep quality and duration (Carrier & Bliwise, 2003). However the brain mechanisms underlying these changes remain unclear. Light is the main synchronizer of circadian rhythmicity (Duffy et al., 1996) and is known to directly affect sleep and other non-visual functions, with a maximal sensitivity to blue light (Lockley et al., 2003; Warman et al., 2003; Lockley et al., 2006; Dijk & Archer, 2009; Vandewalle et al., 2009). Age-related changes in the effect of light on non-visual brain function may therefore underlie modifications in sleep-wake cycle and circadian rhythms. In this study, we investigated the acute effect of blue light exposure on non-visual cognitive brain activity as a function of age.

Methods:
16 young (22.8 ± 4 y.o.) and 14 older (60.9 ± 4.5 y.o.) individuals were alternatively maintained in complete darkness and exposed to short (45s) monochromatic blue (480nm) illuminations at three irradiance levels while performing an auditory working memory 2-back task in a fMRI study. Blue light irradiance levels, presented in a pseudo-random order, were set at $7x10^{12}$, $3x10^{13}$ and 10^{14} photons/cm^2/s and pupil constriction was not inhibited. Data acquisition took place 1h after habitual sleep time. Functional MRI time series were acquired using a 3T MR scanner (TIM-TRIO, Siemens, Germany). Multislice T2*-weighted fMRI images were obtained with a gradient echo-planar sequence using axial slice orientation (32 slices; voxel size: 3.4x3.4x3mm^3 with 30% of gap; matrix size 64x64x32; TR=2000ms; TE=30ms; FA=90°). Data were analyzed with SPM8. New Segment and Dartel toolboxes were used to take into account morphological changes with age. Statistical analysis was conducted in two serial steps, accounting respectively for fixed and random effects. For each subject, changes in brain regional responses were estimated by a general linear model including the responses to the task and their modulation by light irradiance. Statistical inferences were performed ($p<0.05$) after correction for multiple comparisons over small spherical volumes (svc; radius=10mm) located in structures of interest.

Results:
Performance to the task a) was equally high in both age groups (>87%), b) was not significantly different between light conditions, and c) showed no significant age x light intensity interaction ($p>0.05$), preventing behavioural bias of BOLD results. fMRI analyses revealed that, taking into account age-related differences in brain activity independent of the light condition, increasing irradiance enhanced brain responses to the task more strongly in younger than older individuals. These age-related differences in the impact of light irradiance on brain responses to the task were found bilaterally in the thalamus [24 –18 12, Z= 3.92, p_{svc} = 0.004; –12 –26 6, Z = 3.77; p_{svc} = 0.007], and

cerebellum [-20 –40 54, Z = 4.00, p_{svc} = 0.003; 28 –36 –36, Z = 4.46, p_{svc} = 0.001; -18 –40 34, Z = 4.57, p_{svc} = 0.004], the left prefrontal cortex [–44 52 10; Z = 3.40; p_{svc} = 0.022], and left hippocampus [–36 –28 –12; Z = 3.45; p_{svc} = 0.019].

Conclusions:
These results show that the stimulating effect of blue light on non-visual cognitive brain function decreases with age in regions important for cognition (prefrontal cortex, hippocampus, thalamus) and alertness regulation (thalamus). Future analyses will investigate correlations between these fMRI results and pupil constriction measures acquired in the same subjects and will determine if this decrease reflects age-related changes at the level of the brain, the eye, or both.

Lifespan Development
Aging

Abstract Information

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